

# Exhibit A

Exhibit A



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**Scott A. Schroeder, Ph.D., P.E.**  
**Managing Engineer**

**Professional Profile**

Dr. Scott Schroeder is a Managing Engineer in Exponent's Mechanical Engineering practice. Dr. Schroeder has specialized experience in consumer and aerospace product durability and design evaluation, machine guarding, motor bearing failures, heavy machinery, pipeline integrity, and mechanical design evaluation. Dr. Schroeder is also frequently called upon to perform failure analysis of components, devices, and equipment made from metals, plastics, glass, and ceramics.

His areas of expertise include stress analysis, material science, fatigue and fracture, finite element analysis, powder metallurgy, rapid prototyping, mechanics of electronic packaging, metallic and ceramic composites, and creep-fatigue interactions. Dr. Schroeder also specializes in thermal/mechanical testing methods and procedures for advanced materials and aerospace components, elevated temperature and cryogenic environments, in situ electron microscopy deformation studies, fractography, and full-field strain mapping techniques.

Prior to joining Exponent, Dr. Schroeder was a Member of Technical Staff at Rockwell Scientific in the field of mechanics of materials and structural metals, where he conducted research on advanced aerospace composites. In addition, he developed test methodologies for surface mount reliability of microelectronics, and has developed experimental and mathematical models for material behavior. Dr. Schroeder holds 2 patents and has experience negotiating intellectual property issues. He was an instructor at Moorpark College in Moorpark, California.

**Academic Credentials and Professional Honors**

Ph.D., Materials, University of California, Santa Barbara, 1999  
M.S., Engineering Mechanics, University of Wisconsin, Madison, 1989  
B.S., Engineering Mechanics, University of Wisconsin, Madison, 1988

Phi Eta Sigma Freshman Honor Society; Oscar Mayer Four-year scholarship

**Licenses and Registrations**

Registered Professional Mechanical Engineer, California, #M35627

## **Patents**

Patent 6,517,773 B1: Direct Metal Fabrication of Parts with Surface Features Only, February 2003, (with M.R. Mitchell et al.).

Patent 6,365,093 B1: Strengthening Method for Green Form Parts Made From Metal Powder, April 2002 (with H. Ryang).

## **Selected Publications**

Schroeder SA, Ryang H, Spurling R. Advances in direct metal fabrication. Advances in powder metallurgy and particulate materials. Proceedings, 2003 World Congress on Powder Metallurgy and Particulate Materials, Las Vegas, NV, June 2003.

Schroeder SA. Freeform fabrication of metallic components. Proceedings, 1st BCC Conference on Fine, Ultrafine, and Nano Particles, New York, NY, November 1998.

Liang J, Lee PS, Gollhardt N, Schroeder SA. Creep study for fatigue life assessment of solder joints of two lead-free high temperature solder alloys. Electronic Packaging Materials Science IX, MRS Fall Meeting, Boston, MA, 1996.

Liang J, Lee PS, Schroeder SA, Heinrich SM. An integrated fatigue life prediction methodology for optimum design and reliability assessment of solder interconnections. Advances in Electronic Packaging, ASME-EEP 1997; 19-2:1583-1592.

Liang J, Gollhardt N, Lee PS, Schroeder SA, Morris WL. A study of fatigue and creep behavior of four high temperature solders. Fatigue and Fracture of Engineering Materials and Structures 1996; 19-11:1401-1409.

Liang J, Gollhardt N, Lee PS, Schroeder SA, Morris WL. Fatigue and cyclic deformation behavior of high temperature solder alloys. Application of Experimental Mechanics to Electronic Packaging 1995; EEP-Vol. 13/AMD-Vol. 1214.

Heinrich SM, Shakya S, Wang Y, Lee PS, Schroeder SA. Improved yield and performance of ball-grid array packages: Design and processing guidelines for uniform and non-uniform arrays. IEEE Trans., Components, Packaging & Manufacturing Technology Society, Part B: Advanced Packaging, Vol. 19-2, May 1996.

Heinrich SM, Schaefer M, Schroeder SA, Lee PS. Prediction of solder joint geometries in array-type interconnects. Journal of Electronic Packaging, ASME 1996; 118(3):114-121, September.

Heinrich SM, Wang Y, Shakya S, Schroeder SA, Lee PS. Selection of design and process parameters for non-uniform ball-grid arrays. Advances in Electronic Packaging: Toward Failure-Free, Low-Cost Packaging, Vol. 1, ASME-EEP Vol. 10-1:273-288; presented at InterPack '95, Lahaina, HI, March 1995.

Heinrich SM, Schroeder SA, Lee PS. Prediction of solder joint geometries in array-type interconnects. *Journal of Electronic Packaging*, ASME 1995; 118-3:142-147.

Heinrich SM, Shakya S, Wang Y, Lee PS, Schroeder SA. Improved yield and performance of ball-grid array packages: Design and processing guidelines for uniform and non-uniform arrays. *Proceedings, 45th Electronic Components and Technology Conference*, Las Vegas, NV, May 1995. (Selected for "Outstanding Paper Award," 2nd place, Poster Session).

Schroeder SA, Morris WL, Mitchell MR, James MR. A model for primary creep of 63Sn-37Pb solder. *Fatigue of Electronic Materials*, ASTM STP 1153, Schroeder SA and Mitchell MR (eds), American Society for Testing and Materials, Philadelphia, PA, 1994.

Heinrich SM, Schroeder SA, Lee PS. Prediction of solder joint geometries in multiple-bump arrays. *Mechanics and Materials for Electronic Packaging: Volume 1, Design and Process Issues in Electronic Packaging*, Chen, Nguyen, and Winterbottom (eds), ASME AMD-Vol. 195, pp. 11-22, 1994; presented at the 1994 International Mechanical Engineering Congress and Exposition, Chicago, IL, November 1994.

Schroeder SA, Mitchell MR. Torsional creep behavior of 63Sn-37Pb solder. *Advances in Electronic Packaging*, American Society of Mechanical Engineers, New York, NY, Vol. 2, pp. 649-653, 1992.

Enke NF, Kilinski TJ, Schroeder SA, Lesniak JK. Mechanical behaviors of 60/40 tin-lead solder lap joints. *IEEE Trans. on Comp., Hybrids, and Manu. Tech* 1989; 12(4):459-468, December.

### **Books**

Schroeder SA, Mitchell MR (eds). *Fatigue of Electronic Materials*. American Society for Testing and Materials, STP 1153, 1994.

### **Technical Reports**

Artaki I, Noctor D, Desantis C, Desaulnier W, Felton L, Palmer M, Felty J, Greaves J, Handwerker C, Mather J, Napp D, Pan T.-Y, Rosser J, Schroeder SA, Vianco P, Whitten G, Zhu Y. Lead-free Solder Final Report. Final Report of NCMS Project No. 170502, August 1997.

Wright PK, Gilbert S, Chatterjee A, Cook T, Schroeder SA. Damage tolerant design of gamma titanium aluminide. Quarterly Report for Air Force contract F33615-97-C-5291, May 2002.

### **Selected Invited Presentations**

Schroeder SA, Guyer EP, O'Brien MJ. Fracture and fatigue behavior of Si<sub>3</sub>N<sub>4</sub> balls, 2008 AFRL/RZTM Bearing Modeling Summit, August 2008.

Schroeder SA. Advances in direct metal fabricating. WESTEC, Society of Manufacturing Engineers, March 23, 2004.

Bulat W, Schroeder SA, Dadkhah MS. 3D induction heating simulation of a helical gear. ANSYS Conference, 1998.

Schroeder SA, Mitchell MR, Evans AG. Creep crack propagation of 63Sn/37Pb with emphasis on colony boundary deformation and rupture. TMS Annual Meeting, February 1997.

Schroeder SA. Reliability modeling for lead-free microelectronics. TMS Annual Meeting, Orlando, February 9–13, 1997.

Schroeder SA, Morris WL, Mitchell MR, Evans AG. In-situ field emission SEM creep testing of 63Sn/37Pb with emphasis on colony boundary deformation. VIII International Congress on Experimental Mechanics of the Society for Experimental Mechanics, Experimental/Numerical Mechanics in Electronic Packaging session, Nashville, TN June 10–13, 1996.

Schroeder SA, Morris WL, James MR. A microstructural based model of thermal fatigue damage in Pb/Sn alloy solder lap-joints. Lead-Free Solder Workshop, Northwestern University, July 24–26, 1995.

Schroeder SA, Morris WL, Mitchell MR, James MR. Modeling of fatigue damage of solder joints. ASTM Symposium on Fatigue of Electronic Materials, Atlanta, GA, May 17, 1993.

Schroeder SA, Mitchell MR, Morris WL, Dadkhah MS. Damage propagation and reliability in solder joints. SRI Briefing, June 23, 1992.

Schroeder SA, Mitchell MR, Morris WL, Dadkhah MS. Thermal-mechanical behavior of solder joints. University of California, Santa Barbara, CA, July 31, 1992.

Cox BN, Dadkhah MS, Inman RV, Morris WL, Schroeder SA. Mechanisms of compressive failure in woven composites and stitched laminates. Proceedings, 9th DoD/NASA/FAA Conference on Fibrous Composites in Structural Design. Soderquist JR, Neri LM, Bohon LH (eds), pp. 125–138, Lake Tahoe, NV, November 1991.

Schroeder SA, Mitchell MR. Torsional creep behavior of 63Sn-37Pb solder. American Society of Mechanical Engineers/Japanese Society of Mechanical Engineers, San Jose, CA, August 9, 1991.

Cox BN, Dadkhah MS, Inman RV, Mitchell MR, Morris WL, Schroeder SA. Micromechanics of fatigue in woven and stitched composites. Proceedings, 1st NASA Advanced Composites Technology Conference. Davis, Jr. JA, Bohon HL (eds), Seattle, WA, October–November 1990.

Schroeder SA, Mitchell MR, Morris WL, Dadkhah MS. Torsional cyclic shear stress-strain behavior of 63-37 Solder. 1st International Workshop on Materials and Mechanics Issues of Solder Alloy Applications, Santa Fe, NM, June 6–8, 1990.

### **Editorships and Editorial Review Boards**

- Editorial Board, *Journal of Testing and Evaluation*, ASTM International, 2006–present

### **Prior Experience**

Member of Technical Staff, Research Scientist, Rockwell Scientific Company, 1999–2004  
Member of Technical Staff, Rockwell International Science Center, 1996–1999  
Substitute Instructor, Moorpark College, 1996  
Research Specialist, Rockwell International Science Center, 1996–1994  
Technical Specialist, Rockwell International Science Center, 1991–1994  
Senior Technical Associate, Rockwell International Science Center, 1989–1991

### **Project Experience**

Managed a site investigation at a passenger railcar accident in California. The structural damage and accident conditions were assessed.

Evaluated the design suitability of a pipe coupling used in a municipal water pumping station in San Diego, California. Determined the design loads and influence of the manufacturing process.

Managed design and safety reviews of a variety of consumer fitness equipment. Conducted reliability and safety testing for compliance with applicable US and international standards.

Managed and conducted experimental and analytical fatigue and fracture assessments of vehicle components and aerospace materials.

Managed an investigation to determine the scope of a medical device recall. Conducted numerical analyses to assess the viability of several design remediation options.

### **Professional Affiliations**

- American Society for Testing and Materials
  - Committee E28 on Mechanical Testing
  - Committee E08 on Fatigue and Fracture (Chair E08.05.01 Fatigue of Materials)
  - Committee B09 on Metal Powders and Metal Powder Products
  - Committee F08 on Sports Equipment and Facilities
  - Past Chairman Fatigue of Electronic Materials
- American Society of Mechanical Engineers
- American Society of Materials (Former Chair San Fernando Valley Chapter)
- The Minerals, Metals, and Materials Society

# Exhibit B

Exhibit B

# **Mechanical Engineering Reference Manual for the PE Exam**

**Eleventh Edition**

**Michael R. Lindeburg, PE**

**Professional Publications, Inc. • Belmont, CA**

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## MECHANICAL ENGINEERING REFERENCE MANUAL Eleventh Edition

Current printing of this edition: 3

### Printing History

edition number	printing number	update
11	1	New edition. Pressure Vessels chapter revised, about 200 new problems added, many problems converted to multiple choice. Copyright update.
11	2	Minor corrections.
11	3	Minor corrections.

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Engineering strain, given by Eq. 46.2, is calculated from the original length, although the actual length increases during the tensile test. The *true strain* or *physical strain*,  $\epsilon$ , is found from Eqs. 46.8 and 46.9.

$$\begin{aligned}\epsilon &= \int_{L_0}^L \frac{dL}{L} = \ln \left( \frac{L}{L_0} \right) \\ &= \ln(1 + e) \quad [\text{prior to necking}] \quad 46.6\end{aligned}$$

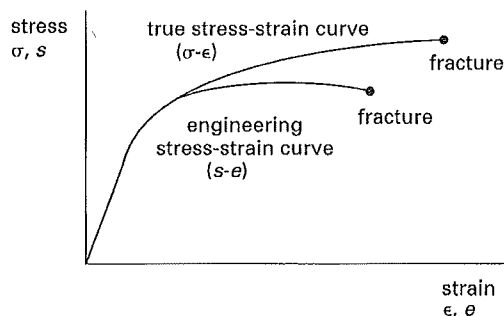
Since the plastic deformation occurs through a shearing process, there is essentially no volume decrease during elongation.

$$A_0 L_0 = AL \quad 46.7$$

Therefore, true strain can be calculated from the cross-sectional areas and, for a circular specimen, from diameters. If necking down has occurred, true strain must be calculated from the areas or diameters, not the lengths.

$$\epsilon = \ln \left( \frac{A_0}{A} \right) = \ln \left( \frac{D_0}{D} \right)^2 = 2 \ln \left( \frac{D_0}{D} \right) \quad 46.8$$

Figure 46.8 compares engineering and true stresses and strains for a ferrous alloy. A graph of true stress and true strain is known as a *flow curve*. Log  $\sigma$  can also be plotted against log  $\epsilon$ , resulting in a straight-line relationship.



**Figure 46.8** True and Engineering Stresses and Strains for a Ferrous Alloy

The flow curve of many metals in the plastic region can be expressed by the relationship of Eq. 46.9.  $K$  is known as the *strength coefficient*, and  $n$  is the *strain-hardening exponent*. Values of both vary greatly with material, composition, and heat treatment.  $n$  can vary from 0 (for a perfectly inelastic solid) to 1.0 (for an elastic solid). Typical values are between 0.1 and 0.5.

$$\sigma = K\epsilon^n \quad 46.9$$

Although true stress and strain are more accurate, almost all engineering work is based on engineering stress and strain, which is justifiable for two reasons: (1) design using ductile materials is limited to the elastic region where engineering and true values differ little, and (2) the reduction in area of most parts at their service stresses is not known; only the original area is known.

### Example 46.1

The engineering stress in a solid tension member was 47,000 lbf/in<sup>2</sup> at failure. The reduction in area was 80%. What were the true stress and strain at failure?

#### Solution

Since engineering stress,  $s$ , is  $F/A_0$ , from Eq. 46.5 the true stress is

$$\begin{aligned}\sigma &= \frac{s}{1 - RA} \\ &= \frac{47,000 \frac{\text{lbf}}{\text{in}^2}}{1 - 0.80} = 235,000 \text{ lbf/in}^2\end{aligned}$$

From Eq. 46.6, the true strain is

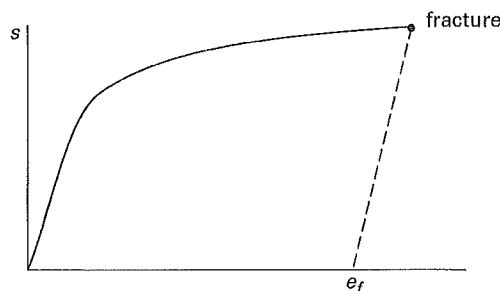
$$\epsilon = \ln \left( \frac{1}{1 - 0.80} \right) = 1.61 \quad (161\%)$$

## 8. DUCTILITY

A material that deforms and elongates a great deal before failure is said to be a *ductile material*. (Steel, for example, is a ductile material.) The *percent elongation*, short for *percent elongation at failure*, is the total plastic strain at failure. (Percent elongation does not include the elastic strain, because even at ultimate failure the material snaps back an amount equal to the elastic strain.)

$$\begin{aligned}\text{percent elongation} &= \frac{L_f - L_0}{L_0} \times 100\% \\ &= e_f \times 100\% \quad 46.10\end{aligned}$$

The value of the final strain to be used in Eq. 46.10 is found by extending a line from the failure point downward to the strain axis, parallel to the linear portion of the curve. This is equivalent to putting the two broken specimen pieces together and measuring the total length.



**Figure 46.9** Percent Elongation

Highly ductile materials exhibit large percent elongations. However, percent elongation is not the same as *ductility*.

$$\text{ductility} = \frac{\text{ultimate failure strain}}{\text{yielding strain}} \quad 46.11$$

# Exhibit C

Exhibit C

Oxford Dictionaries Online  
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elongated(e·lon·gat·ed)

Pronunciation: /i'lonɡ,ɡætɪd, i'læŋ-/

*adjective*

unusually long in relation to its width:

*the creature had two sets of arms and an elongated face*